Constant of Atomic Nuclei and New Equation of Strong Nuclear Force

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Abstract

We present new equations of atomic nuclei (new equation of calculating strong nuclear force and constant connecting nuclear radius and atomic mass number) with calculations and results in agreement with known determined calculations. All nuclei are consisting of nucleons (protons & neutrons) as certain masses with certain diameters at certain distances with certain number of its constituents with certain velocities hold and maintained by certain fundamental force (strong nuclear force), so the main equations of nuclei are controlled by these physical parameters. It is found that the distribution of particles in the nuclei is uniform for their masses and diameters. The calculations confirmed that the mass and diameter of any nucleus give constant value. The new equation with a new nuclei constant is used to calculate previously undetermined experimental radii. The new equation of strong nuclear force can be determined by three main physical parameters (mass, distance, velocity of light).

Keywords: nuclei, force, mass, distance, time

1. Introduction

In 1911, Rutherford found that at the center of every atom is a nucleus. Atomic nuclei consisting of electrically positive charged protons and electrically neutral neutrons [1]. The protons and neutrons are held together by the strong nuclear force. The volume of nucleus represents much less than 0.01 % of the volume of the atom and typically contains more than 99.9 % of the atom mass. After the discovery of neutrons [2]. Models for a nucleus were developed [3-5].

The nuclear radius is considered to be one of the main quantities that any model must predict. For stable nuclei the nuclear radius is proportional to the cube root of the atomic mass number of

the nucleus, and particularly in nuclei containing many nucleons as they arrange in spherical configurations.

The stable nucleus has nearly a constant density and therefore the nuclear radius can be approximated by the following equation

$$R = r_0 A^{1/3} \qquad (1)$$

Where A is the atomic mass number and $r_0 = 1.2\times10^{-15}$ m. In this equation the constant changes by 0.2 fm, depending on the nucleus.

The small systems such as nuclei and atoms have a constant value as a result of their homogenous distribution of their constituents. It is found that the atom as nucleus and electrons at certain distances contained in a certain area with a certain uniform distribution forming certain system (atom) with a certain constant. The same result with certain constant is found for atomic nuclei.

2. Results and Discussions

The Physical relations and laws can be expressed in terms of the main physical parameters responsible for their origin. Protons and neutrons at certain distances contained in a certain area with a certain uniform distribution forming certain system (nucleus) with a certain constant. The strong nuclear force is acting only at certain distance in the range of a few femto meters and its main role is to form and bound the nuclei and is determined by three main physical parameters (mass, distance, velocity of light).

The present approach and method to determine the radii of atomic nuclei is different. We atomic nuclei as equal in spherical geometrical shape. All radii are then obtained self consistently by using simple equation connecting nuclear radius and atomic mass number.

As a result of the uniform distribution of the particles inside nuclei, the square root of the mass of any nucleus is proportional with its area

$$\sqrt{m} \propto a \qquad (2)$$

$$\sqrt{m} = const \times 4\pi \times r^2 \qquad (3)$$

$$cons = \frac{\sqrt{m}}{4\pi \times r^2} = 2.2\times10^{15} \quad \sqrt{kg} / m^2 \qquad (4)$$

from which the following equation (5) can be deduced

$$r^2 = \frac{\sqrt{m}}{4\pi \times cons} \qquad (5)$$

The calculated mass of any nuclei by using equation (3) is identical with actual nuclei mass values and the calculated radius of any nuclei by using equation (5) is consistent and in good agreement with determined experimental values as indicated in Table 1

where

a is the area of any nucleus

m is the mass of any nucleus

cons. is constant value for any nucleus

r is the radius of any nucleus

All calculations confirmed that there is constant value for nuclei relating the square root of the mass of any nucleus and its area. Table (1) lists the constant value of the nuclei by using equation (4) compared with experimental determined values of nuclear radii [7-9] and determined values by using equation (1).

Comparison of the present calculations and results for radii of atomic nuclei with the available experimental values gives a good agreement between them.

Table (1) Physical parameters of nuclei

Atomic Number	Symbol	Name	Square Root Mass Number (kg)	Experimental Radius (m)	New Radius (m)	Radius Eq. (1) (m)	Constant $\sqrt{kg} / m^2$
1	H	Hydrogen	4.09×10^{-14}	0.88×10^{-15}	1.20×10^{-15}	1.20×10^{-15}	2.2×10^{15}

2	He	Helium	8.17×10^{-14}	1.67×10^{-15}	1.69×10^{-15}	1.90×10^{-15}	2.2×10^{15}
3	Li	Lithium	1.08×10^{-13}	2.44×10^{-15}	1.97×10^{-15}	2.29×10^{-15}	2.2×10^{15}
4	Be	Beryllium	1.23×10^{-13}	2.51×10^{-15}	2.11×10^{-15}	2.49×10^{-15}	2.2×10^{15}
5	B	Boron	1.34×10^{-13}	2.40×10^{-15}	2.21×10^{-15}	2.66×10^{-15}	2.2×10^{15}
6	C	Carbon	1.42×10^{-13}	2.47×10^{-15}	2.25×10^{-15}	2.74×10^{-15}	2.2×10^{15}
7	N	Nitrogen	1.53×10^{-13}	2.55×10^{-15}	2.35×10^{-15}	2.89×10^{-15}	2.2×10^{15}
8	O	Oxygen	1.63×10^{-13}	2.69×10^{-15}	2.43×10^{-15}	3.02×10^{-15}	2.2×10^{15}
9	F	Fluorine	1.78×10^{-13}	2.89×10^{-15}	2.52×10^{-15}	3.20×10^{-15}	2.2×10^{15}
10	Ne	Neon	1.84×10^{-13}	3.00×10^{-15}	2.58×10^{-15}	3.25×10^{-15}	2.2×10^{15}
11	Na	Sodium	1.96×10^{-13}	2.99×10^{-15}	2.65×10^{-15}	3.41×10^{-15}	2.2×10^{15}
12	Mg	Magnesium	2.01×10^{-13}	3.02×10^{-15}	2.69×10^{-15}	3.46×10^{-15}	2.2×10^{15}
13	Al	Aluminium	2.12×10^{-13}	3.06×10^{-15}	2.75×10^{-15}	3.59×10^{-15}	2.2×10^{15}
14	Si	Silicon	2.16×10^{-13}	3.12×10^{-15}	2.79×10^{-15}	3.64×10^{-15}	2.2×10^{15}
15	P	Phosphorus	2.28×10^{-13}	3.18×10^{-15}	2.87×10^{-15}	3.76×10^{-15}	2.2×10^{15}
16	S	Sulfur	2.31×10^{-13}	3.26×10^{-15}	2.90×10^{-15}	3.81×10^{-15}	2.2×10^{15}
17	Cl	Clorine	2.43×10^{-13}	3.36×10^{-15}	2.95×10^{-15}	3.92×10^{-15}	2.2×10^{15}
18	Ar	Argon	2.58×10^{-13}	3.42×10^{-15}	3.04×10^{-15}	4.10×10^{-15}	2.2×10^{15}
19	K	Potassium	2.55×10^{-13}	3.43×10^{-15}	3.02×10^{-15}	4.06×10^{-15}	2.2×10^{15}
20	Ca	Calcium	2.58×10^{-13}	3.47×10^{-15}	3.04×10^{-15}	4.10×10^{-15}	2.2×10^{15}
21	Sc	Scandium	2.74×10^{-13}	3.54×10^{-15}	3.13×10^{-15}	4.26×10^{-15}	2.2×10^{15}
22	Ti	Titanium	2.83×10^{-13}	3.59×10^{-15}	3.21×10^{-15}	4.36×10^{-15}	2.2×10^{15}
23	V	Vanadium	3.92×10^{-13}	3.60×10^{-15}	3.25×10^{-15}	4.45×10^{-15}	2.2×10^{15}

24	Cr	Chromium	2.95×10^{-13}	3.64×10^{-15}	3.28×10^{-15}	4.48×10^{-15}	2.2×10^{15}
25	Mn	Manganese	3.03×10^{-13}	3.03×10^{-15}	3.30×10^{-15}	4.56×10^{-15}	2.2×10^{15}
26	Fe	Iron	3.06×10^{-13}	3.73×10^{-15}	3.33×10^{-15}	4.59×10^{-15}	2.2×10^{15}
27	Co	Cobalt	3.14×10^{-13}	3.78×10^{-15}	3.38×10^{-15}	4.67×10^{-15}	2.2×10^{15}
28	Ni	Nickel	3.13×10^{-13}	3.77×10^{-15}	3.37×10^{-15}	4.66×10^{-15}	2.2×10^{15}
29	Cu	Copper	3.17×10^{-13}	3.88×10^{-15}	3.42×10^{-15}	4.79×10^{-15}	2.2×10^{15}
30	Zn	Zinc	3.32×10^{-13}	3.92×10^{-15}	3.45×10^{-15}	4.84×10^{-15}	2.2×10^{15}
31	Ga	Gallium	3.42×10^{-13}	3.99×10^{-15}	3.50×10^{-15}	4.94×10^{-15}	2.2×10^{15}
32	Ge	Germanium	3.47×10^{-13}	4.06×10^{-15}	3.54×10^{-15}	5.01×10^{-15}	2.2×10^{15}
33	As	Arsenic	3.54×10^{-13}	4.09×10^{-15}	3.56×10^{-15}	5.06×10^{-15}	2.2×10^{15}
34	Se	Selenium	3.63×10^{-13}	4.14×10^{-15}	3.61×10^{-15}	5.14×10^{-15}	2.2×10^{15}
35	Br	Bromine	3.66×10^{-13}	4.15×10^{-15}	3.63×10^{-15}	5.17×10^{-15}	2.2×10^{15}
36	Kr	Krypton	3.75×10^{-13}	4.18×10^{-15}	3.67×10^{-15}	5.25×10^{-15}	2.2×10^{15}
37	Rb	Rubidium	3.79×10^{-13}	4.20×10^{-15}	3.71×10^{-15}	5.29×10^{-15}	2.2×10^{15}
38	Sr	Strontium	3.83×10^{-13}	4.22×10^{-15}	3.73×10^{-15}	5.33×10^{-15}	2.2×10^{15}
39	Y	Yttrium	3.86×10^{-13}	4.24×10^{-15}	3.75×10^{-15}	5.35×10^{-15}	2.2×10^{15}
40	Zr	Zirconium	3.92×10^{-13}	4.30×10^{-15}	3.77×10^{-15}	5.41×10^{-15}	2.2×10^{15}
41	Nb	Niobium	3.94×10^{-13}	4.32×10^{-15}	3.78×10^{-15}	5.43×10^{-15}	2.2×10^{15}
42	Mo	Molybdenum	4.00×10^{-13}	4.38×10^{-15}	3.81×10^{-15}	5.49×10^{-15}	2.2×10^{15}
43	Tc	Technetium	4.02×10^{-13}		3.82×10^{-15}	5.51×10^{-15}	2.2×10^{15}
44	Ru	Ruthenium	4.11×10^{-13}	4.46×10^{-15}	3.90×10^{-15}	5.58×10^{-15}	2.2×10^{15}

45	Rh	Rhodium	4.15×10^{-13}	3.49×10^{-15}	3.91×10^{-15}	5.62×10^{-15}	2.2×10^{15}
46	Pd	Palladium	4.23×10^{-13}	4.53×10^{-15}	3.94×10^{-15}	5.68×10^{-15}	2.2×10^{15}
47	Ag	Silver	4.25×10^{-13}	4.54×10^{-15}	3.95×10^{-15}	5.71×10^{-15}	2.2×10^{15}
48	Cd	Cadmium	4.34×10^{-13}	4.60×10^{-15}	3.98×10^{-15}	5.78×10^{-15}	2.2×10^{15}
49	In	Indium	4.38×10^{-13}	4.61×10^{-15}	4.02×10^{-15}	5.83×10^{-15}	2.2×10^{15}
50	Sn	Tin	4.46×10^{-13}	4.64×10^{-15}	4.03×10^{-15}	5.90×10^{-15}	2.2×10^{15}
51	An	Antimony	4.51×10^{-13}	4.68×10^{-15}	4.05×10^{-15}	5.95×10^{-15}	2.2×10^{15}
52	Te	Tellurium	4.62×10^{-13}	4.73×10^{-15}	4.10×10^{-15}	6.04×10^{-15}	2.2×10^{15}
53	I	Iodine	4.60×10^{-13}	4.75×10^{-15}	4.09×10^{-15}	6.03×10^{-15}	2.2×10^{15}
54	Xe	Xenon	4.70×10^{-13}	4.78×10^{-15}	4.13×10^{-15}	6.09×10^{-15}	2.2×10^{15}
55	Cs	Cesium	4.80×10^{-13}	4.80×10^{-15}	4.14×10^{-15}	6.12×10^{-15}	2.2×10^{15}
56	Ba	Barium	4.80×10^{-13}	4.83×10^{-15}	4.15×10^{-15}	6.18×10^{-15}	2.2×10^{15}
57	La	Lanthanum	4.81×10^{-13}	4.85×10^{-15}	4.17×10^{-15}	6.21×10^{-15}	2.2×10^{15}
58	Ce	Cerium	4.85×10^{-13}	4.87×10^{-15}	4.18×10^{-15}	6.23×10^{-15}	2.2×10^{15}
59	Pr	Praseodymium	4.86×10^{-13}	4.89×10^{-15}	4.18×10^{-15}	6.25×10^{-15}	2.2×10^{15}
60	Nd	Neodymium	4.92×10^{-13}	4.94×10^{-15}	4.19×10^{-15}	6.28×10^{-15}	2.2×10^{15}
61	Pm	Promethium	4.93×10^{-13}		4.19×10^{-15}	6.30×10^{-15}	2.2×10^{15}
62	Sm	Samarium	5.02×10^{-13}	5.05×10^{-15}	4.21×10^{-15}	6.38×10^{-15}	2.2×10^{15}
63	Eu	Europium	5.04×10^{-13}	5.10×10^{-15}	4.22×10^{-15}	6.40×10^{-15}	2.2×10^{15}
64	Gd	Gadolinium	5.12×10^{-13}	5.14×10^{-15}	4.26×10^{-15}	6.47×10^{-15}	2.2×10^{15}
65	Tb	Terbium	5.15×10^{-13}	5.06×10^{-15}	4.28×10^{-15}	6.50×10^{-15}	2.2×10^{15}
66	Dy	Dysprosium	5.22×10^{-13}	5.20×10^{-15}	4.32×10^{-15}	6.54×10^{-15}	2.2×10^{15}

67	Ho	Holmium	5.25×10^{-13}	5.20×10^{-15}	4.34×10^{-15}	6.58×10^{-15}	2.2×10^{15}
68	Er	Erbium	5.30×10^{-13}	5.26×10^{-15}	4.37×10^{-15}	6.61×10^{-15}	2.2×10^{15}
69	Tm	Thulium	5.31×10^{-13}	5.22×10^{-15}	4.38×10^{-15}	6.63×10^{-15}	2.2×10^{15}
70	Yb	Ytterbium	5.38×10^{-13}	5.30×10^{-15}	4.41×10^{-15}	6.68×10^{-15}	2.2×10^{15}
71	Lu	Lutetium	5.41×10^{-13}	5.37×10^{-15}	4.42×10^{-15}	6.71×10^{-15}	2.2×10^{15}
72	Hf	Hafnium	5.47×10^{-13}	5.34×10^{-15}	4.45×10^{-15}	6.75×10^{-15}	2.2×10^{15}
73	Ta	Tantalum	5.50×10^{-13}	5.35×10^{-15}	4.46×10^{-15}	6.78×10^{-15}	2.2×10^{15}
74	W	Tungsten	5.54×10^{-13}	5.36×10^{-15}	4.48×10^{-15}	6.82×10^{-15}	2.2×10^{15}
75	Re	Rhenium	5.59×10^{-13}	5.35×10^{-15}	4.51×10^{-15}	6.84×10^{-15}	2.2×10^{15}
76	Os	Osmium	5.63×10^{-13}	5.40×10^{-15}	4.53×10^{-15}	6.89×10^{-15}	2.2×10^{15}
77	Ir	Iridium	5.67×10^{-13}	5.39×10^{-15}	4.55×10^{-15}	6.92×10^{-15}	2.2×10^{15}
78	Pt	Platinum	5.71×10^{-13}	5.42×10^{-15}	4.57×10^{-15}	6.95×10^{-15}	2.2×10^{15}
79	Au	Gold	5.74×10^{-13}	5.43×10^{-15}	4.58×10^{-15}	6.98×10^{-15}	2.2×10^{15}
80	Hg	Mercury	5.79×10^{-13}	5.45×10^{-15}	4.60×10^{-15}	7.02×10^{-15}	2.2×10^{15}
81	Ti	Thallium	5.85×10^{-13}	5.47×10^{-15}	4.61×10^{-15}	7.07×10^{-15}	2.2×10^{15}
82	Pb	Lead	5.88×10^{-13}	5.49×10^{-15}	4.63×10^{-15}	7.09×10^{-15}	2.2×10^{15}
83	Bi	Bismuth	5.91×10^{-13}	5.52×10^{-15}	4.65×10^{-15}	7.12×10^{-15}	2.2×10^{15}
84	Po	Polonium	5.91×10^{-13}	5.55×10^{-15}	4.65×10^{-15}	7.12×10^{-15}	2.2×10^{15}
85	At	Astatine	5.92×10^{-13}		4.66×10^{-15}	7.13×10^{-15}	2.2×10^{15}
86	Rd	Radon	6.09×10^{-13}	5.69×10^{-15}	4.69×10^{-15}	7.26×10^{-15}	2.2×10^{15}
87	Fr	Francium	6.10×10^{-13}	5.69×10^{-15}	4.69×10^{-15}	7.28×10^{-15}	2.2×10^{15}

88	Ra	Radium	6.14×10^{-13}	5.72×10^{-15}	4.71×10^{-15}	7.31×10^{-15}	2.2×10^{15}
89	Ac	Actinium	6.16×10^{-13}		4.72×10^{-15}	7.32×10^{-15}	2.2×10^{15}
90	Th	Thorium	6.22×10^{-13}	5.78×10^{-15}	4.75×10^{-15}	7.37×10^{-15}	2.2×10^{15}
91	Pa	Protactinium	6.21×10^{-13}		4.74×10^{-15}	7.36×10^{-15}	2.2×10^{15}
92	U	Uranium	6.30×10^{-13}	5.85×10^{-15}	4.78×10^{-15}	7.43×10^{-15}	2.2×10^{15}
93	Np	Neptunium	6.29×10^{-13}		4.77×10^{-15}	7.42×10^{-15}	2.2×10^{15}
94	Pl	Plutonium	6.38×10^{-13}	5.89×10^{-15}	4.82×10^{-15}	7.49×10^{-15}	2.2×10^{15}
95	Am	Americium	6.37×10^{-13}	5.90×10^{-15}	4.81×10^{-15}	7.48×10^{-15}	2.2×10^{15}
96	Cm	Curium	6.42×10^{-13}	5.85×10^{-15}	4.83×10^{-15}	7.53×10^{-15}	2.2×10^{15}
97	Bk	Berkelium	6.42×10^{-13}		4.83×10^{-15}	7.53×10^{-15}	2.2×10^{15}
98	Cf	Californium	6.47×10^{-13}		4.85×10^{-15}	7.56×10^{-15}	2.2×10^{15}
99	Es	Einsteinium	6.48×10^{-13}		4.86×10^{-15}	7.58×10^{-15}	2.2×10^{15}
100	Fm	Fermium	6.55×10^{-13}		4.89×10^{-15}	7.62×10^{-15}	2.2×10^{15}
101	Md	Mendelevium	6.56×10^{-13}		4.90×10^{-15}	7.63×10^{-15}	2.2×10^{15}
102	No	Nobelium	6.57×10^{-13}		4.91×10^{-15}	7.64×10^{-15}	2.2×10^{15}
103	Lr	Lawrencium	6.66×10^{-13}		4.93×10^{-15}	7.71×10^{-15}	2.2×10^{15}
104	Rf	Rutherfordium	6.67×10^{-13}		4.94×10^{-15}	7.72×10^{-15}	2.2×10^{15}
105	Db	Dubnium	6.68×10^{-13}		4.95×10^{-15}	7.73×10^{-15}	2.2×10^{15}
106	Sg	Seaborgium	6.69×10^{-13}		4.96×10^{-15}	7.74×10^{-15}	2.2×10^{15}
107	Bh	Bohrium	6.70×10^{-13}		4.97×10^{-15}	7.75×10^{-15}	2.2×10^{15}
108	Hs	Hassium	6.69×10^{-13}		4.97×10^{-15}	7.74×10^{-15}	2.2×10^{15}
109	Mt	Meitnerium	6.80×10^{-13}		4.98×10^{-15}	7.82×10^{-15}	2.2×10^{15}

110	Ds	Darmstadtium	6.86×10^{-13}		5.00×10^{-15}	7.86×10^{-15}	2.2×10^{15}
111	Rg	Roentgenium	6.86×10^{-13}		5.00×10^{-15}	7.86×10^{-15}	2.2×10^{15}
112	Cn	Copernicium	6.91×10^{-13}		5.02×10^{-15}	7.90×10^{-15}	2.2×10^{15}
113	Nh	Nihonium	6.91×10^{-13}		5.02×10^{-15}	7.90×10^{-15}	2.2×10^{15}
114	Fi	Flerovium	6.96×10^{-13}		5.03×10^{-15}	7.94×10^{-15}	2.2×10^{15}
115	Mc	Moscovium	6.96×10^{-13}		5.03×10^{-15}	7.94×10^{-15}	2.2×10^{15}
116	Lv	Livermorium	6.99×10^{-13}		5.04×10^{-15}	7.97×10^{-15}	2.2×10^{15}
117	Ts	Tennessine	7.00×10^{-13}		5.04×10^{-15}	7.98×10^{-15}	2.2×10^{15}
118	Og	Oganesson	7.02×10^{-13}		5.05×10^{-15}	7.99×10^{-15}	2.2×10^{15}

It is noticed that all atomic nuclei have the same value (2.2×10^{15}). This means and indicate that all atomic nuclei have the same constant value relating the square root of mass and area.

3.3. Strong Nuclear Force

The strong nuclear force of nuclei with its constituents (protons & neutrons) as certain masses at certain distances with spin and orbital velocities comparable to the velocity of light can be determined by the following equation as the electromagnetic force [10].

$$F=\frac{4c^2\times M}{d}$$

$$F=\frac{4c^2\times(m_1+m_2)}{d} \qquad (5)$$

from equation (5)

$$\frac{F\times d}{4\times(m_1+m_2)}=c^2 \qquad (6)$$

This means that the three main physical parameters (strong nuclear force, distance, mass) for any two particles equals square of velocity of light.

Where M is the sum of two particles, m_1 is the mass of the first particle and m_2 is the mass of the second particle, c is the velocity of light, d is the distance between particles.

4. Calculating Strong Nuclear Force

By using equation (5) for two nucleons with their known determined values:

- proton mass = 1.7×10^{-27} kg,
- distance between proton and proton $\sim10^{-15}$ m
- c is the velocity of light $\sim 3\times10^{8}$ m/s

it is found that the value of strong nuclear force is approximately 1.2×10^{6} N

and by using equation (6)

$$\frac{F\times d}{4\times(m_1+m_2)} = 9\times10^{16} = c^2 \text{ (square of velocity of light)}$$

According to the above calculations and results by increasing the number of particles for heavy nuclei, the strong nuclear force is linearly additive as binding energy and the result of three physical parameters (force & distance & mass) in equation (6) for any nucleus gives constant value square of velocity of light.

5. Conclusion

The uniform distribution of nucleons (protons & neutrons) inside nucleus with certain masses and certain area in each nucleus leads to the existence of a common constant for all nuclei.

The square root of mass and the area of any nucleus give a constant value in calculations and results in nuclei radii in good agreement with known experimental determined values. The new equation of nuclei with new nuclei constant is used to calculate previously undetermined experimental nuclei radii.

The strong nuclear force is produced as a result of existing nucleons at certain distance in the range of femto meter and the main role of strong nuclear force is to form and bound the nucleus

and can be calculated with physical parameters (masses of any two nucleons, distance between them and the velocity of light).

References

1. E. Rutherford, Philosophical Magazine, 6, 669, 688 (1911).
2. J. Chadwick, J, Proceedings of the royal society, 136 (830): 692–708 (1932).
3. D. D. Iwanenkov, Nature. 129 (3265): 798 (1932).
4. W. Heisenberg, Z. Phys. 77 (1–2): 1–11 (1932).
5. W. Heisenberg, Z. Phys. 78 (3–4): 156–164 (1932).
6. W. Heisenberg, Z. Phys. 80 (9–10): 587–596 (1933).
7. K. S. Krane, Introductory Nuclear Physics. Wiley-VCH (1987).
8. A. I. Miller. Early Quantum Electrodynamics: A Sourcebook, Cambridge University Press, Cambridge, pp. 84–88 (1995).
9. I. Angeli, K. P. Marinova, Atomic Data and Nuclear Data Tables, 99, 69 (2013).
10. M. R. Sanad, Proceedings of the Romanian Academy, series A, 25(4), pp 301-306 (2024)